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ABSTRACT

The feasibility of generalized approaches to training military personnel in the use of different types of sonar/acoustic warfare systems was explored. The initial phase of the project consisted of the analysis of representative sonar and acoustic equipment to identify training areas and operator performance requirements that could be subjected to generalized training methods. The degree of commonality in operator tasks, skill, and knowledge requirements for each system was considered. Phase 2 involved the evaluation of existing training methods. A high degree of commonality was found in operator tasks for surface and subsurface systems involving stimuli of low to moderate uncertainty, procedure following, and simple motor responses. The application of generalized training concepts was judged feasible for sonar operators, although further research is needed on the exact approaches to be taken. (DGC)

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THE FEASIBILITY OF GENERALIZED ACOUSTIC SENSOR OPERATOR TRAINING

HONEYWELL INC.
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This program explored the feasibility of a generalized approach to acoustic sensor operator training and resulted in recommendations concerning implementation. The program involved the analysis of the task, skill, and knowledge requirements for acoustic sensor operators (ASO) across a representative sample of sensor systems.

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The program approach was divided into three major phases.

Phase I involved the establishment of an ASO task data base which contained behavioral task statements descriptive of the ASO's operational activities. During Phase II these task statements were taxonomically encoded and analyzed to determine commonalities in task requirements for various acoustic sensor systems in the sample. Additional analyses of the coded task data were used to identify common skill and knowledge requirements for those tasks. During Phase III these analyzed data were interpreted to develop an estimate of the feasibility of Generalized Acoustic Sensor Operator Training (GASOT), based on task, skill and knowledge commonality. Recommendations were then developed for the nature of a GASOT system.

In addition, during Phase III the feasibility of implementing was addressed. Issues addressed included the potential modifiability of a GASOT system to meet the training requirements of new acoustic systems, and the impact of implementing a GASOT course on the existing ASO training pipeline.

Finally, recommendations were made concerning the feasibility of Generalized ASO training based on task, skill, and knowledge commonalities and the Navy training environment.

SUMMARY

The training of operators for the numerous sonar/acoustic warfare systems existing in the surface and subsurface fleets has traditionally relied upon the use of operational equipment, or in other words, has been equipment-specific training. Advancement of the operational capabilities of sonar and acoustic warfare systems translates directly into operating tasks of greater complexity and requirements for highly skilled operator personnel. At the same time, fiscal constraints in the operating and training environments are reducing the capabilities and resources for training personnel to operate the sonar systems of growing technological complexity. Also, fiscal constraints will limit the continued development of system-specific simulators for training sonar and acoustic warfare systems.

Consequently, the Navy training community is faced with a challenge and urgent requirement to increase the effectiveness of training sonar operators with a simultaneous reduction in training costs. The generalized approach to training appears to offer some potential for providing instruction in sonar operator functions at substantial cost and training advantages.

This report provides the results from the first phase of a research program. The objective was to determine the feasibility and applicability of using a generalized training approach for operators of sonar and acoustic warfare equipment.

The approach consisted of analyzing a representative sample of surface and subsurface sonar and acoustic warfare equipment to identify the training areas and operator performance requirements which could be supported by a generalized training approach. Behavioral task statements of operator functions for 14 sonar systems were derived primarily from sonar system specifications and operator task analyses. These statements were taxonomically coded and categorized by system platform, system type, tactical activity, and behavioral function to provide the data base for commonality analysis.

Results from the data analysis were examined from two reference points. First, the feasibility of a sonar operator training approach in terms of degree of commonality in operator task, skill and knowledge requirements. Secondly, the feasibility of generalized training was addressed on

SUMMARY (continued)

the basis of available training and hardware simulation technologies for providing the stimulus and response capabilities necessary to train the common operator tasks, skills, and knowledge associated with sonar and acoustic warfare systems.

Findings indicated a high degree of commonality in operator tasks for surface and subsurface systems involving stimuli of low to moderate uncertainty, procedure following, and simple motor responses. Descriptively, the common job elements for the sonar operator consisted of activating a pushbutton or rotary switch in accordance with a specific rule or procedure when a familiar signal light appears. This commonality was found principally in the Set-Up/Turn-On, Search/Detect, and Track phases of the tactical mission. Thus, the training of operators for current and future surface and subsurface sonar systems should emphasize the skills and knowledge associated with the capability to set-up and configure the system to maximize the acoustic information presentation. Observed from the findings was the trend that the sonar system optimization function is becoming more of a team task with direction being provided by the Sonar Supervisor.

The application and utilization of the generalized training concept was judged feasible for sonar operator training on the basis of the present investigation. The investigation has resulted in an identification of skill and knowledge requirements which are common to many of the sonar operator functions particularly at the procedure-following level. The training and simulation technology, required for implementing a generalized approach to the training of sonar operators, is available, but research on the validation of specific principles, fidelity of simulation, degree of system specification necessary for transfer, and cost/training effectiveness of such an approach is recommended before implementation. However, the findings and recommendations developed should offer valuable guidance in the design of sonar operator training since they are based on an analysis of skill and knowledge requirements common to the surface and subsurface sonar operator jobs.

PREFACE

The generalized training approach has gained acceptance during recent years and there is a strong likelihood that as more experience is acquired the approach will become more firmly established in the training community. The experience with generalized training has been primarily in the training of maintenance personnel.

A research program has been initiated to determine the feasibility of applying a generalized approach to the training of sonar operators. This report provides the results from an analysis of sonar operator task requirements associated with surface and submarine acoustic sensor systems. Findings from the analysis indicate that a generalized approach has applicability in the training of equipment operation and procedure following skills.

These results provide sufficient grounds for continuing the research and development effort to identify the particular simulation and instructional characteristics and to evaluate possible alternatives for configuring a generalized training approach and/or system for sonar operators. Program effort will proceed to examine the various simulation and training alternatives and applicability of these alternatives for increasing the effectiveness of the training of sonar operators.

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WILLIAM P. LANE
Scientific Officer

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (continued)

SECTION I

INTRODUCTION

Background and Problem Statement

This study was undertaken to explore the feasibility of applying generalized techniques to the training of acoustic sensor (sonar) operators. Several pragmatic considerations indicated the need for this study.

First the Navy must find new and less costly approaches to accomplish its various missions. Because training is a major budgetary item for the Navy, this area is a prime candidate for cost reduction efforts.

Several recent activities within the naval establishment appear to have been directed at the reduction of costs through reorganization. Examples include a trend toward centralization of functions and the growing use of the common core approach to training various basic skills.

Paralleling the Navy's search for economy through reorganization is a continuing attempt to employ the most cost-effective procedures in accomplishing its missions. Focusing on the Navy's training mission, increased cost-effectiveness is being sought through the application of new instructional techniques and training technologies.

One such technique is that of generalized training. Over the past several years, the Navy has explored the feasibility of and, in some cases, implemented generalized training courses. Those investigations have involved training for such diverse skills as sonar equipment maintenance[1], submarine diving control[2], underwater fire control system maintenance[3],

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[1] J. F. DePauli and E. L. Parker, The Introduction of the Generalized Sonar Maintenance Trainer into Navy Training for an Evaluation of its Effectiveness, Technical Report NAVTRADEVCEN 68-C-0005-1, April 1969, Naval Training Device Center, Orlando, Florida.

[2] J. C. Lamb, W. R. Bertsche and B. G. Carey, A Study of Generalized Submarine Advanced Casualty Ship Control Training Device, Technical Report NAVTRADEVCEN 69-C-0117-1, August 1970, Naval Training Device Center, Orlando, Florida.

[3] J. F. DePauli, A Study of the Feasibility and Desirability of Developing a Generalized Underwater Fire-Control System Maintenance Trainer, Technical Report NAVTRADEVCEN 69-C-0152-1, January 1970, Naval Training Device Center, Orlando, Florida.

and the operation of electronic warfare equipment[4]. In the cases where a generalized training course has been developed and used, there is evidence that this approach is highly effective[5].

In considering other potential applications for generalized training, the area of Acoustic Sensor Operator (ASO) training is a prime candidate due to the multiplicity of systems and training hardware in use. Historically, the training of ASO's has involved separate training courses and devices for nearly every piece of operational equipment. That approach has resulted in a proliferation of high fidelity, system-specific training devices. In addition to being costly, this approach overlooks the possibility that more effective training for certain basic ASO skills may be accomplished using a generalized approach.

The specific issue addressed in this study was whether there was evidence to support the consideration of a generalized approach for ASO training.

Approaches to Generalized Training

Consideration of how generalized training might be applied in training ASO's led to the identification of three major alternatives. Generalized training can be basically defined as using a common core curricula in the process of training tasks, skills, and/or knowledge required by a number of different jobs. Theoretically, most job families possessing a common set of task requirements should be trainable with a generalized approach. This assumption, however, is not adequate for either the issue of concept feasibility or that of application. Even if commonality does exist between tasks required in various jobs, there is an additional need to identify the specific skills and knowledge to be trained and then to select an appropriate approach for accomplishing that training.

Typically, application of a generalized training has been considered from one of the following approaches. The first involves specification of a generalized simulation based on functional similarities between a set of

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4 D. C. I. Blake, Feasibility Study for Generalized Electronic Warfare Training System (u)(GEWTS), Technical Report, NAVTRAEQUIPCEN 73-C-0159-1, March 1974, Naval Training Equipment Center, Orlando, Florida.

5 DePauli and Parker, op. cit.

specific equipments. For the Generalized Sonar Maintenance Trainer[6], this approach first involved the identification of common electronic circuits across several different sonar systems. Then a generalized training simulator was constructed containing the most common of those circuits. The curricula developed for use with the Generalized Sonar Maintenance Trainer focussed on the skill and knowledge required to understand, and the tasks required to maintain, each of the common circuits.

A second approach to generalized training involves the simulation in a single console of all relevant features and functions for an entire set of operational equipments. Although this composite approach would permit the training of a total set of specific skills in a specific hardware setting, a major problem might be the large number of controls, displays, and functions required. As the similarity decreases between the operational systems being represented, the requirement for including additional unique displays, controls, etc., increases, thus calling into serious question the usefulness of this approach.

A third approach which might be taken requires no generalized simulation. Rather, a single set of specific operational hardware could be used. Here the assumption must be made that the functions, controls, and displays contained in a single operational system are representative of the entire family of systems for which training is to be provided. Likewise, the associated task, skill, and knowledge requirements must be determined to be sufficiently similar. If all of these conditions could be met, it would then be possible to train for the operation of any similar system using a single, specific equipment simulator. This approach is most analogous to the training provided in Naval Class "A" schools today.

Program Goal

The general objective of this program was to investigate the feasibility and make recommendations for the implementation of Generalized Acoustic Sensor Operator Training. Accomplishment of this objective involved: 1) establishment of an ASO task data base, 2) analysis of that data to identify the level of task commonality across acoustic systems, 3) identification of

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[6] J. F. DePauli, Design Characteristics of a Digital Sonar Maintenance Trainer: An Adjunct to Device 14E22, Technical Report NAVTRADEVCEN 69-C-0268-1, June 1971, Naval Training Device Center, Orlando, Florida.

skill and knowledge requirements for common ASO tasks, 4) determination of the amount and character of skill and knowledge commonality across acoustic systems, 5) development of generalized ASO training feasibility recommendations, and 6) development of a preliminary specification for the training technology appropriate for generalized ASO training.

SECTION II

METHOD AND PROCEDURE

Overview

The procedure for this investigation was divided into three major phases.

Phase I involved the establishment of a data base containing the operator task requirements for representative acoustic sensor systems.

Phase II consisted of analyses to determine task commonality across acoustic system categories and tactical mission phases. These analyses were performed on the behavioral task descriptions and the skill and knowledge requirements identified in Phase I.

Phase III involved interpretation of the results of those data analyses to assess feasibility of a generalized training concept. Interpretation was a two-step process. The first step addressed the question of whether the generalized concept was feasible on the basis of commonality of task occurrence. The second step considered the feasibility of implementating a generalized training program in light of its potential impact on the existing training community.

The methodology used in each phase is discussed in detail below.

Phase I - Establishment of Acoustic Sensor Operator Task Data Base

The tasks, skills, and knowledge required to operate various acoustic sensor systems were identified. This information was derived primarily from sonar system specifications and from operator task analyses. Ancillary information was taken from requirements for operator selection and advancement and, where available, from training course curricula, lesson plans, and objectives. These behavioral task statements of operator activity were then categorized according to sensor system platform, system type, tactical activity, and behavioral function. This constitutes the data base for commonality analysis.

Selection of Acoustic Sensor Systems--Preliminary survey identified over one hundred acoustic sensor systems in operational use or under development. Included in this group were primary sonar, auxiliary and fire control systems from surface, subsurface, and shore based platforms. Security restrictions prevented access to data on shore based systems. Thus, this category was not considered further. Table 1 depicts the designators of those systems included in the initial group.

A screening process was instituted to select the systems from this group which met the following criteria:

- Systems currently in operational use
- Projected longevity (into the 1980 time frame)
- Operator task analysis available
- Operator training conducted at a shorebased facility
- Tactical utilization of equipment

These criteria were used in discussions at various naval schools, laboratories, and systems commands to review and reduce the system sample. The requirement for operational use in the 1980's immediately eliminated many of the older, often one-of-a-kind systems. Further, with an emphasis upon tactical utilization of equipment, the auxiliary equipment such as bathythermographs, fathometers, tape recorders, noise analyzers, and the like were also excluded. These systems were concluded to be outside the main stream of the operator's tactical performance. Similarly, operation of fire control equipment was excluded since it too represented a different category of operator behavior. The most significant factor in determining system inclusion for this study was the availability of adequate operator task data. Those systems preceded by an asterisk in table 1 constituted the sample used for this study.

Some operator task data was available for each model of the SQS-26, yet no single model had sufficient data associated with it to be analyzed alone. Consequently, a decision was made to combine the data available for the SQS-26 series systems. This combined task set provided an accurate indication of the types and numbers of major tasks required to operate all models of the SQS-26. The Subsurface Combination category of systems is represented solely by the BQQ-5. While this may appear inappropriate in terms of the numbers of such systems in the fleet, this

TABLE 1. SYSTEMS CONSIDERED FOR INCLUSION IN STUDY

SURFACE					SUBSURFACE				
Active	Passive.	Comb.	Aux.	F/C	Active	Passive	Comb	Aux.	F/C
*AN/SQS - 4	AN/SQR-14	*AN/SQS-26SERIES	AN/BQC-1	MK-105	AN/SQS -4	*AN/BQR-2	AN/BQS-6	AN/BQA-3	MK-112
-19	-17	AN/SQS-26AX(R)	AN/UQC-1	-111	-10	-3	-11	-8	-113
* -23D-G		-26BX	AN/UNQ-4	-114	-11	-4	-12	AN/BQC-1	-101
-29/32		-26CX	-7	-116	-49	* -7	-13	AN/BQH-1	-106
* -35(v)		AN/SQS-53	AN/WLR-6		*AN/BQS-2	-8	*AN/BQQ-5	-2	AN/BQG-2
* -38		-54	HIPP		-4	-10	TRIDENT	-4	-4
-39/46		*AN/SQQ-23PAIR	ASPECT		-10	* -15		-5	SAWS
-51			TRR		-14	-16		AN/BQN-3	
-56					-15	* -19		-4	
AN/SQQ-14					-49/51	* -20		AN/BQN-3	
AN/UQS- 1					AN/QHB-1	* -21		-4	
						-22		AN-BQQ-1	
								-2	
								-3	
								DUUG	
								AN/UQN-1	
								AN/BNQ-7	
								-8	
								AN/UQC-1	
								AN/UQH-1	
								AN/WLR-6	
								-9	
								AN/WQC-12	
								AN/WQC -2	

* Included in current study.

system is projected to be the basic submarine sonar of the future. Finally, as a pragmatic concern, there was complete task data on the BQQ-5 system and and little or none on the others in the subsurface combination category.

Data Collection. -Concurrent with the process of system selection was the acquisition of documentation on sonar systems and operator tasks. Ideally, this documentation would be in the form of equipment operation activities for a representative tactical scenario from which descriptive behavioral task data could be taken. Over two hundred documents and technical reports were collected and reviewed. (A complete listing of this bibliography is contained in Volume II of this report.) Few of the collected documents provided information in the necessary detail for this study. Most were found to contain information of either a non-operator or non-system nature or else were too general to be of value.

Data Categorization. -In addition to operator tasks themselves, a determination was also made of the operational environment, tactical mission, and functional activity wherein these operator tasks occurred. To aid the planned analysis, a Data Categorization Matrix (table 2) was prepared so that tasks could be cross-referenced by each of those factors.

The two operational environments considered were the Surface and Subsurface. Subordinate to each environment, the tactical sonar systems were segregated according to function into Active, Passive, or Combination (i.e., Active and Passive) categories.

On the operator side of the data matrix, five mission phases were differentiated: Set-Up/Turn-On, Search/Detect, Track, Classify, and Communicate. It was hypothesized that each of these mission phases would have unique types of operator tasks associated with them. The Set-Up/Turn-On phase was defined as involving system initialization activities which occurred prior to any period of operation. The Search/Detect phase began with either a no contact situation or with one or more targets being automatically tracked in one mode of system operation and the operator searching for other targets in the same or a different system mode. The event of sonar contact terminated the Search/Detect phase. The Track phase included manual tracking, establishment of automatic tracking parameters, and interaction with fire control. The Classification phase emphasized aural and visual cue extraction, cue correlation, and decision-making activities. Finally, the Communicate phase consisted of operator tasks with both a communication input and output.

TABLE 2. DATA CATEGORIZATION MATRIX

		ENVIRONMENT												
		SURFACE					SUBSURFACE							
		Type					Type							
		Active				Combination	Active	Passive						Combination
Mission Phase	Operator Functions*	SQS4	SQS23	SQS35	SQS38	SQS26-23	BQS4	BQR 2	BQR 7	BQR 19	BQR 20	BQR 21	BQQ 3	BQQ5
1. Set-up/Turn-on	1. Select System Parameters													
	2. Adjust System Parameters													
	3. Monitor Displays Visually													
	4. Monitor Displays Aurally													
	5. Read Displays Visually													
	6. Manipulate Controls													
	7. Follow Procedures													
	8. Detect Signal Presence													
	9. Discriminate Signals Visually													
	10. Discriminate Signals Aurally													
	11. Interpret Signals													
	12. Classify Signals													
2. Search/Detect	*													
3. Track	*													
4. Classify	*													
5. Communicate	*													

* The same 12 operator function categories are used for each mission phase.

Tasks included in this phase were not limited to those involving verbal communications; also included were communications with light flashes and button pushes when of a purely communicative nature.

For each mission phase, twelve functional activities were differentiated. Each activity represented specific types of operator behaviors. These functions and their definitions are shown in table 3.

Phase II - Determination of Task, Knowledge, and Skill Commonality

Determining the commonality of operator tasks, knowledge and skills across a variety of acoustic sensor systems required both data reduction and data analysis.

Data Reduction. -Data reduction consisted of three basic steps: 1) extraction of operator task descriptions from the literature, 2) translation of those task descriptions into numeric form via a taxonomic scheme, and 3) classification of each task according to the Data Categorization Matrix described above. The objective of this process was to convert verbal description of each task into its essential elements and in a form suitable for computer analysis.

1. Task Extraction. -Of the documents assembled not all contained data in a behavioral task statement format. Frequently, task descriptions were in narrative form necessitating the generation and construction of related behavioral task statements. Tasks included in the data base had definable input and output parameters and an inferable cognition. Thus, all task statements contained the three components of: stimulus, cognitive process, and response.

2. Taxonomic Coding. -Each task in the data base was encoded using a numerical taxonomy.[7] Use of such a taxonomy has the distinct advantage of permitting analysis of tasks to obtain a precise definition commonality which is defined as the occurrence of two or more identical task codes. Task commonality can, therefore, be discussed in terms of percentages, frequencies, and other nominal statistics.

[7] B. W. Yaeger, A Numerical Task Taxonomy, Honeywell Technical Document No. 232-70, March 1969.

TABLE 3. BEHAVIORAL DESCRIPTIONS FOR OPERATOR FUNCTIONS

Operator Function	Behavioral Description
Select System Parameter	Make an initial setting or change a major system mode
Adjust System Parameter	Make a fine adjustment in system configuration or make an alteration in a subsystem mode
Monitor Display Visually	Attention to or search for a signal in a primary visual display or system indicator
Monitor Display Aurally	Attention to or search for a signal via head phones, loudspeakers, or intercom
Read Analog/Digital Display	Extraction of information from a visual indicator
Manipulate Controls	Manual tracking, cursor alignment or other psychomotor act
Follow Procedures	Implementation of known procedures, including commands, interactions, or plans
Determine Signal Presence	Detection of a suprathreshold event or signal, either aural or visual
Discriminate Signals Visually	Make a visual comparison between two or more alternatives
Discriminate Signals Aurally	Make an aural comparison between two or more alternatives
Interpret Signals	Make a categorization of aural or visual signal. May require a decision
Classify Signals	Make a specific characterization and identification of a signal or event

	TASK ELEMENTS						
	STIMULUS		COGNITION			RESPONSE	
	Categories		Categories			Categories	
	Modality	Information Uncertainty	Perception	Information Processing	Action Selection	Modality	Complexity
Codes and Corresponding Levels of Categories	1 Visual 2 Aural 3 Touch 4 Combination of two or more modalities 5 Other	1 Noise 2 Simple, one-bit, no uncertainty 3 Simple, single-parameter, discrete 4 Simple, multi-parameter, discrete 5 Complex, multi-parameter, discrete, continuous 6 Complex, multi-parameter, continuous 7 Complex multi-parameter	1 Detection 2 Discrimination 3 Recognition 4 Identification 5 Classification	1 Reflex 2 Data analysis 3 Problem diagnosis 4 Concept formation 5 Innovation/creation	1 In action 2 Seeks information 3 Follow specific rule 4 Follow general rule	1 Visual orienting 2 Verbal 3 Motor 4 Combination of two or more modalities 5 Other	1 Simple, discrete 2 Controlled, single parameter, discrete 3 Controlled, multi-parameter, discrete 4 Complex, skilled, continuous 5 Compound, multi-parameter, continuous 6 High skill, fine control
Numerical Task Code Positions	1	2	3	4	5	6	7

Figure 1. Numerical Task Taxonomy Summary

A summary of the taxonomy used in this study is depicted in figure 1. The complete form with definitions and examples is contained in appendix A of this report. The version of this taxonomy used in this study is a revision of the form used in an earlier report by the same authors.[8] The modifications were made to the earlier version to provide a more accurate reflection of the acoustic sensor environment.

Within this numerical taxonomy, each task is considered in terms of three elements: (Stimulus, Cognition, and Response. The Stimulus and Response elements are each represented by two digits: one for modality and one for complexity/uncertainty. The Cognition element is represented by three digits, corresponding to perceptual processing, information processing, and action selection activities.. An example of the use of this taxonomy is shown in figure 2. Each task element is assigned a level as a function of its behavioral characteristics.

Type	Task Description
Verbal Task Statement	On verbal command, follows orders and turns on equipment by pressing ON pushbutton.
Coded Numerical Representation	2 2 - 3 2 3 - 3 1

Figure 2. Example Task and Numerical Taxonomic Code

Using this taxonomy in a previous study,[9] it was found that at least two judges were required to reliably assign numerical codes to behavioral task statements. This number of judges was used in the current study to ensure that all critical features of each task statement were considered when translating into the seven-digit code format. Once in a numerical form, all specific task characteristics,

8 R. W. Daniels, D. G. Alden, A. I. Kanarick, T. H. Gray, R. L. Feuge, Automated Operator Instruction in Team Tactics, Technical Report NAVTRADEVCEN 70-C-0310-1, January 1972, Naval Training Device Center, Orlando, Florida.

9 Ibid.

such as position in an operation sequence or criticality, were lost except as reflected in the resulting taxonomic code.

3. Task Sorting. -The final step of data reduction consisted of categorizing each task according to the mission phase and operator function where it occurred (See Table 2 - Data Categorization Matrix). The product of this step was a determination of task frequency by matrix cell, for each task statement was associated with one and only one of the cells of the matrix. By summing over matrix rows, we could tabulate commonality by Mission Phase and by Operator Function across Mission Phases. When summing over matrix columns, task commonality could be tabulated by System Environment, System Function, and by System Type. It was at this point that the initial estimates of task commonality were obtained, that is, commonality in terms of the cells, rows, and columns of the matrix where the highest task frequencies occurred. Subsequent analyses of this data, discussed below, permitted determination of the degree of commonality by types of tasks. That is, those subsequent analyses allowed an answer to the question: do these cells represent many different task codes or a few task codes, each accounting for many task occurrences?

Data Analyses. -To warrant consideration of a generalized approach to acoustic sensor operator training data was needed on:

- Amount of commonality in the tasks required to operate various acoustic sensor systems.
- Amount of commonality in the skill and knowledge requirements for those common operator tasks.

To obtain answers to those questions, the data was sorted and analyzed in several ways.

1. Analyses of Seven Digit Task Codes. -For each unique seven digit taxonomic code (i.e., a behavioral task description), the following data summaries were produced:
    - Total number of task (7 digit code) occurrences
    - Number of task occurrences for each environment
    - Number of task occurrences for each system type

- Number of task occurrences for each specific acoustic sensor system
- Number of task occurrences for each tactical mission
- Number of task occurrences for each mission/function combination

Additionally, these data were summarized by data categorization matrix cell. For each cell of the Data Categorization Matrix, data were summarized as follows: 1) by task codes, 2) by the number of different task statements accounted for by code, and 3) by the systems wherein the task statements were observed.

2. Partial Task Codes. -Each seven digit task code was partitioned into four combinations of three elements. These combinations were hypothesized to correspond to skill and knowledge factors required of operators in order to accomplish the task.

Two aspects of a <u>knowledge factor</u> were proposed: a peripheral and a central aspect. The peripheral aspect included the task elements of stimulus modality, stimulus uncertainty, and cognitive perception (task elements 12-3). The central aspect included only the cognitive triad, perception-processing-action selection (task elements -345-). A <u>skill factor</u> was postulated to be represented by the taxonomic task elements of action selection, response modality, and response complexity (5-67). A final factor related to <u>task difficulty</u> and was represented by stimulus uncertainty, cognitive information processing, and response complexity (-2-4-7).

The same data summaries as for the seven digit codes were generated for each of these partial codes. These data, together with that from analyses of the seven digit codes, provided the information upon which was based a determination of generalized ASO training feasibility.

Phase III - Determination of Concept Feasibility

In this phase of the program, two types of feasibility were addressed. The first was feasibility of generalized ASO training based only upon a consideration of operator task, skill, and knowledge commonality. The second

type related to feasibility of implementing a generalized ASO training program. As such, consideration of implementation feasibility focussed on the questions of concept feasibility and dealt with issues of training technology and practice.

Generalized ASO Training Feasibility. -Summary data produced by the analyses of task codes was used only to determine the feasibility of generalized ASO training based upon the commonality of those tasks, skills, and knowledge. A complete, objective answer to the question of feasibility requires the determination of several other parameters (transfer, cost, etc.). However, subjective and logical estimates for the sufficiency of those other dimensions were made from the current data.

A multistep process was used in arriving at an estimate of feasibility based on task, skill, and knowledge commonality. Following summarization of the seven-digit and three-digit task code data, a criterion was established to determine which frequency of code occurrence was adequate to indicate that sufficient commonality existed for that code to be included in subsequent analyses. The criterion which was established required that only those codes which occurred with a frequency equal to at least one percent of the total data sample would be included. Selection of this criterion was not based on any preconception of how much commonality is adequate to demonstrate feasibility. Rather, the amount of commonality needed to indicate feasibility was and is unknown. Selection of one percent was based on the belief that, if significant commonality did exist, it would simply not be overlooked.

The task codes meeting the one percent criterion formed a subset known as the "most common" codes. This restricted set of "most common" task codes were then analyzed to identify the character and source of commonality. Data summaries for these analyses, typically in the form of cumulative frequencies, were designed to localize the stimulus, cognition, and response requirements common across the various categories of acoustic sensor systems. Where common requirements were found, the implications for training were identified.

Implementation Feasibility. -The objective of this activity was to develop a preliminary definition of the specification for a Generalized Acoustic Sensor Operator training system.

That specification was to define the activities or functions to be performed by the instructor, the trainee, and the hardware. Aspects of the training

system, which are required in order to provide trainees with experience in the critical system activities, were defined by the commonality analyses. The contents of the specification was defined by the skill and knowledge commonality. Attention was focussed on the stimulus and response capabilities required to train the common tasks, skills, and knowledge identified earlier. The emphasis here was upon the technology required for training versus simply simulating operational sensor hardware.

Two basic factors were considered in preparing a preliminary training specification. One relates to whether generalized acoustic sensor operator training can be realistically implemented, given the state-of-the-art training and hardware simulation technologies. The second factor relates to the ability of the specification concept to deal with modifications in sensor system configuration as well as related changes in the operator's task.

SECTION III

RESULTS AND DISCUSSION

The purpose of the analyses conducted for this study was to identify the amount and character of common ASO task, skill, and knowledge requirements. This report section is organized by the types of analyses performed. Summaries of all data are presented in appendix B.

The initial subsection describes the data base. A second subsection presents results from analyses of the total seven-digit task codes. The results of those analyses relate to task commonality across sensor systems. The final subsection presents results of analyses performed on partial (three-digit) task codes. These analyses identify commonalities of ASO skill and knowledge requirements across sonar systems.

Description of the Data Base

Numerically encoded behavioral task statements were used to determine the commonality of ASO task, skill, and knowledge requirements. The study data base consisted of 2,483 behavioral statements representing the tasks required to operate the 14 different sensor systems in the sample. Table 4 shows the distribution of these task codes according to associated sensor system and by the mission segment and operator function to which they apply. This table shows that the greatest degree of operator activity occurs during the Search/Detect and the Track mission phases.

Analysis of Total Task Codes

Commonality Across Sensor Systems. -An initial analysis determined the number of common and unique tasks performed by ASO's in operating various sensor systems. For this analysis, each seven-digit task code was compared with every other task code in the data base. For a task code to be considered common with any other code, it was necessary that the codes match exactly. Thus, codes 11-111-11 and 11-111-11 were common, whereas codes 11-111-11 and 21-111-11 were not.

This analysis resulted in the identification of 443 different task codes from among the 2,483 total operator tasks in the sample. Within this group, the frequency of code occurrence ranged between one and 273.

TABLE 4. FREQUENCY OF TASK OCCURRENCE BY MISSION AND FUNCTION

		ENVIRONMENT														
		SURFACE						SUBSURFACE								
		TYPE						TYPE								
		ACTIVE				COMB.*		ACTIVE	PASSIVE						COMB.	
MISSION	FUNCTION	SQS 4	SQS 23A-G*	SQS 35(V)	SQS 38	SQS 26	SQS 23pair	BQS 4	BQR 2	BQR 7	BQR 19	BQR 20	BQR 21	BQQ 3	BQQ 5	Σ→
Set-Up/ Turn-On	1	11	11	34	26	8	20	8	4	9	10	21	50	4	32	248
	2	1	2	6	6	14	8	4	1	3	8	3	11		47	114
	3					4		1					2		1	8
	4										1					1
	5						4						6		3	13
	6														2	2
	7										6		1	1	1	9
	8					11	2				3		2		50	68
	9						1								5	6
	10															0
	11										1				2	3
	12															0
	↓Σ	12	13	40	32	37	35	13	5	12	29	24	72	5	143	472
Search/ Detect	1						16	3	2	2	3	3	7	1	17	54
	2	2	25			25	72	8	4	4	5	9	34	6	228	422
	3	1		2	2	[illegible]	10	3	[illegible]	1	2	2	7	3	48	89
	4	1	3	2	2	8	1		1	1	2		11		4	36
	5	2				3	11	4			2	3	39		33	97
	6	3				3	12	4			1	1	15	2	8	49
	7	1	3	2	2	11			[illegible]	5	1			2	3	35
	8	2	3	2	2	17	30	2	1	1	3		8	2	3	76
	9						2		1	1	1		2		12	19
	10						21				1				4	26
	11		3				11		6	6			7	2	9	44
	12												1		2	3
	↓Σ	12	[illegible]	8	8	76	186	24	21	21	21	19	131	18	437	950
Track	1		1	1	1	2	14	2					14		5	40
	2	17	13	10	[illegible]	47	35		4	4			52		50	247
	3	17				19	7	1	1	1	2		7		11	66
	4					8							5		2	15
	5						7	1	1	1	4		57		75	146
	6	4	6	1	1	19	16	1	3	3	3		31		20	108
	7	1	3	2	2	14			1	1					30	59
	8					15	6	1					3		1	27
	9					16							11		31	58
	10						1						1		9	11
	11					5	1		5	5			1		37	54
	12					1									12	13
	↓Σ	[illegible]	28	14	13	152	88	6	15	15	[illegible]	[illegible]	182	0	283	844
Classify	1			3	3		8					4				18
	2			8	8		30		2	2		1	2			53
	3												1			1
	4						2						1			3
	5						2									2
	6			2	2		8									12
	7			1	1				1	1						4
	8															0
	9			1	1		1		2	2		1	1			9
	10						2									2
	11	2		2	2				3	3			1	4		17
	12	1	1	1	1		2		1	1			1	2		11
	↓Σ	3	1	18	18	0	55	6	9	9	0	6	7	6	0	132
Communicate	1						4						1			5
	2															0
	3						1									1
	4															0
	5															0
	6															0
	7					1	7	1	4	4	5		20		6	48
	8						4									4
	9															0
	10															0
	11						1						10		1	12
	12					9							6			15
	Σ	0	0	0	0	10	17	1	4	4	5	0	37	0	7	85
	Σ↓	66	79	80*	71	275	381	44	54	61	64	48	428	29	802	2183
		296				656		44	685						802	

*See Table 2.

Since the major objective was to determine the amount and character of task commonality, codes occurring infrequently were not of major interest. Rather, emphasis was placed on those codes having a "sufficient" frequency (commonality) to relate to the question of generalized ASO training feasibility. As indicated above, the operational definition of sufficiency was that task codes having frequencies equal to or greater than one percent of the total data base would be included in further analyses. With a data base containing 2,483 task codes, those codes occurring with frequencies of 25 (24.83) or greater became the focus of subsequent analyses.

Thirteen unique codes met the one percent criterion (table B-1). This group of codes represents 43 percent of the total task occurrences in the data-base. Furthermore, the three most frequent codes alone accounted for 25.3 percent of the task occurrences.

The three codes with the highest frequencies of occurrence differ very little from one another in terms of the behavioral dimensions represented. In fact, the major difference is in the stimulus modality (1st code digit). Tasks represented by a stimulus modality code of "1" indicate situations in which an operator sees the stimulus, e.g., a light comes on, a signal appears on a display. A modality code of "4" depicts the case where the operator hears a verbal order first, then visually checks some indicator.

A second difference among the three most frequent codes is in response complexity (7th code digit). Here the difference between code numbers "1" and "2" is between the operator pressing a pushbutton and selecting a position on a multiposition rotary switch.

A more detailed inspection of the 13 common task codes provides insights into the general character of common ASO tasks. A preponderance of "1's" in the stimulus modality position (1st code digit) indicates that there is almost a total reliance on visual stimuli in the performance of common ASO tasks. The second code digit refers to the information uncertainty of those visual stimuli. Here a mixture of "2's", "3's", and "5's" depicts situations involving from simple, one-bite stimuli with no uncertainty to those with dynamic or moving indicators such as a CRT display or bearing indicator.

Perhaps the most interesting aspect of stimuli associated with common tasks was the absence of totally aural stimuli. This finding, however, is consistent with the functions the operator is performing when common tasks occur and will be addressed later in this section.

The cognitive requirements of common tasks were also very similar. With but three exceptions, the cognitive element was coded "-323-". This code depicts a situation where the operator must recognize a familiar stimulus, analyze that information, and select, from among a known set, the specific rule or procedure to follow in making his response.

The picture presented by the response element of the common task codes highlights a simple eye-hand coordinative output. Examples of such a response might be pressing a button or flipping a switch on the operator's console.

Overall, then, the tasks which were found to be commonly performed by operators of various different acoustic systems stress simple procedure following behaviors. There is no evidence that characteristics of the high-skill tasks, such as target classification, are common across acoustic sensor systems.

Commonality by Operator Function and Mission Phase. -In addition to identifying the common types of tasks performed by ASO's, determination of generalized training feasibility also required information relating the functions performed by the operator to the mission phase involved. Such information relates to the scope of the curriculum required for generalized training and involved the question of whether a limited number of training scenarios was sufficient, or whether the full gamut of the ASO's job should be included. The same information provided an indication of the amount and fidelity of simulation required in providing this training.

Table B-2 contains the 13 most common task codes in an Operator Function x Mission Phase matrix. The significant information provided by this table is identification of the tactical functions operators are performing when accomplishing the various common tasks. Worthy of note is a heavy grouping of tasks occurring in the Select and the Adjust System Parameter rows of the matrix. This finding indicates that ASO's perform many common tasks in the manipulation of their equipment. Also significant in terms of common task distribution in this matrix is that the highest frequency of common task occurrence is during the Set-Up, Search, and Track mission phases.

Coupled with a paucity of common task occurrences in both the Classify and Communicate mission phases and in the operator function dealing with the classification process across all mission phases, these findings suggest that focus of ASO training should be upon system operation requirements.

These findings also indicate that the tasks requiring high skill levels, e.g., target classification, should not be stressed in a training system designed to be responsive to the needs of a large sample of acoustic sensor operators.

Commonality by Acoustic System Category.-Sensor systems were categorized on the dimensions of platform or environment, and according to type of operation, i.e., Active, Passive, or Combination. Both of these categorizations were used with the intent of identifying common operator requirements within but not necessarily across categories. The discovery of high levels of task commonality only within categories would indicate the potential value of providing an ASO training program for a specific group of systems. Although application of such a program would be much narrower than one designed to train all ASO's, training which focuses on a specific platform or system type still significantly reduces the cost of ASO training.

The distribution of the 13 most common task codes across all systems showed that the most frequently occurring task code (42-323-31) was not the most representative, occurring in only four systems (table B-3). The single code which occurred often and in the operation of all sample systems was 13-323-32. A second frequently occurring task code was 12-323-31.

There were 942 task statements associated with systems in the Surface environment category and 1,531 with the Subsurface environment category. For a task to be considered common across environments, it had to occur in at least half of <u>both</u> the Surface and Subsurface systems. The analysis of task commonality by system environment produced two common and very similar codes: 12-323-31 and 13-323-32.

The only difference between those two codes was the complexity of the stimulus and response. However, a major similarity exists between these codes and the highest frequency codes found in the previous analysis of task commonality across systems. It appears that the results of this analysis supports the earlier finding and that there is no evidence, based on task commonality, to indicate the need for separate surface and subsurface oriented training programs.

A final analysis of the seven-digit code data explored task commonality within each acoustic sensor system type. As there were no Passive systems in the Surface environment category, this analysis dealt with only the Active- and Combination-type categories.

Of the five Active systems, four were associated with the Surface environment. Analysis of the tasks required to operate these surface category systems yielded a single code which was common to all: 13-323-32. Within the Subsurface-Active category, two common codes were found: 12-323-32 and 43-323-32. Each of the above commonalities accounted for less than 50 task occurrences (>two percent of the task sample).

Similar analyses were conducted for systems in the Passive and Combination-type categories. Here, again, commonality was found for the same specific task codes as emerged in the initial analysis for commonality.

Summary of Analyses by Seven-Digit Total Task Codes. - The data obtained from analyses of the seven-digit task codes present a rather clear picture. The characteristics of the codes found in common across all systems indicate that about 25 percent of an ASO's job involves rather simple tasks. The two most representative and common codes underscore this fact. These tasks require perception of simple visual stimuli, a procedure following cognitive activity and a simple eye-hand coordinative response.

It should not be concluded from these data that this relatively simple type of task is the most important that ASO's perform. On the contrary, common tasks and/or frequently occurring tasks are probably not the most difficult or critical. However, in considering the relationship of this finding on the potential applicability of generalized training for ASO's, it does suggest the emphasis for such training. Namely, and based only on commonality and frequency of task occurrence, the definition of a Generalized Acoustic Sensor Operator Training (GASOT) system should place a heavy emphasis on providing training in the basic procedural skills needed for equipment operation.

The basis for suggesting the focus of GASOT is strengthened by results from the analyses of Mission Phase and Operator Function where task commonality was found. Specifically, the greatest commonality was found in the Set-Up, Search, and Track Mission phases. Although not surprising, this finding does verify the fact that certain parts of an ASO's job are quite similar regardless of the specific acoustic system he might be operating. Also, the concentration of common task codes found in the Selecting and Adjusting Controls and the Visually Reading Displays functions for those three missions further emphasize the "basic skill" nature of that commonality.

Analysis of Partial Task Codes. - Another basic question in determining GASOT feasibility relates to the specific skills and knowledges which must be trained. Such information is needed both in the development of a GASOT curriculum and for designing any training hardware which may be required.

Because the data base was composed of behavioral task statements, each such statement identifies the stimulus, cognitive, and response elements of the task. Separate analysis of these task elements provides a profile of the common skill and knowledge requirements of ASO's.

A series of analyses was run to identify common ASO skill and knowledge requirements. These analyses involved selected parameters which were extractable from total task codes. Table 5 presents the identification of the taxonomic elements and their definition for each factor analyzed.

Again, for these "partials" analyses, the data base was analyzed to identify the partial codes representing commonality > one percent of the 2,483 task codes. Likewise, the one percent criterion value was 25 occurrences. Subsequently, the partial code associated with each skill or knowledge factor shown in table 5 was analyzed further to determine the amount and character of commonality.

The same three analyses were run for each factor shown in Table 5 as for the total task codes:

- Overall commonality of partial task codes (factors).
- Distribution of common task codes across acoustic systems.
- Distribution of common task codes within the Data Categorization Matrix.

Results of those analyses are presented in the following paragraphs.

1. Perceptual Knowledge Factor. The perceptual knowledge factor is postulated to reflect requirements placed on ASO's for perceiving and processing incoming stimulus information. Taxonomic elements included in this factor are stimulus modality and complexity together with cognitive perceptual processing.

   The analysis for common codes relating to the perceptual knowledge factor resulted in identification of 22 codes which represented 85 percent of the data base (table B-4).

   The greatest number of codes associated with the perceptual knowledge factor (20/22) involved either a purely visual or a combination aural-visual stimulus (first digit a 1 or 4, respectively). Again, as in the previous analysis of total codes, there existed a paucity of purely aural stimuli (first digit a 2).

TABLE 5. TAXONOMIC ELEMENTS ANALYZED TO DETERMINE SKILL AND KNOWLEDGE REQUIRED OF ASO'S

Taxonomic Elements	Factor	Description	
		Code Digit	Definition
12-3XX-XX	Perceptual Knowledge	1 2 3	Stimulus Modality Stimulus Complexity Perceptual Processing
XX-345-XXX	Cognitive Knowledge	3 4 5	Perceptual Processing Information Processing Action Selection
XX-XX5-67	Response Skill	5 6 7	Action Selection Response Modality Response Complexity
X2-X4X-X7	Task Difficulty	2 4 7	Stimulus Complexity Information Processing Response Complexity

Stimulus uncertainties (2nd digit) found associated with those predominately visual stimuli ranged from noise only (1) to highly complex and multiparameter (6) stimulus. Overall, the complex multiparameter stimulus (6) was the most frequently occurring code digit in the common perceptual knowledge codes. This finding suggests that in thinking about the range of common experiences to which ASO's should be exposed, consideration must be given to including the full gamut of stimulus uncertainties.

The major cognitive or perceptual processing elements found in these common perceptual knowledge codes reflects an emphasis on detection, discrimination and recognition activities. Equally important is the fact that activities associated with stimulus identification and classification were not associated with those common codes to any large degree.

In summary, then, the picture presented by analyses of the perceptual knowledge factor substantiate the findings of total code analyses, showing that for common tasks the ASO's stimulus environment involves a predominantly visual stimulus ranging over several uncertainty levels and requiring familiarization and/or pretraining for recognition.

Regarding the representativeness of common perceptual knowledge factor codes; the current analyses again produced a picture similar to that obtained from total code analyses (table B-5). Specifically, the perceptual knowledge factor codes found to exist across all systems in the current sample were; 13-3, 12-3, and 15-2, These codes depict visual stimuli with moderate undertainty requiring previous experience for processing.

A final analysis of the perceptual knowledge factor identified the Operator Functions and Mission Phases associated with the occurrences of that factor (table B-6). The data indicate that a majority of occurrences of common perceptual knowledge factor codes was coupled with the Select and Adjust System parameters operator functions and with the Search and Track phases of the mission.

In summary, analysis of the perceptual knowledge factor has substantiated the findings obtained from the total code analyses. The range of stimulus uncertainty found in these analyses suggests that ASO's require experience with a representative sample of stimulus uncertainties. This dimension may translate into a subsequent definition of training display fidelity requirements, depending on the outcome of subsequent analyses in this report section.

2. Cognitive Knowledge Factor. Of the 12 codes in this group which met the one percent commonality criterion, the most common cognitive code was -323- (table B-7). This code is familiar from the total code analysis, as it was the most common there too. The -323- code represents a "procedure following" cognitive activity, combining recognition, data analysis and acting according to a specific rule. Thus, the data indicate an ASO's job is heavily weighted with routine activity for which procedures and/or rules exist.

Across acoustic systems, two cognitive codes were found associated with all systems in the sample (table B-8). These codes were -323- and -223-. The major difference between these codes is in the perceptual processing element which indicates that two separate perceptual processing requirements exist - those of discrimination and recognition.

Distribution of the cognitive factor common codes within the Operator Function x Mission Phase matrix indicates a continued emphasis of the Search and Track Mission phases (table B-9). However, the single operator function of Adjust System Parameters is the area where the greatest occurrence of common cognitive codes was found.

3. Responsive Skill Factor. Six of the 18 common responsive skill factor codes were found to account for nearly 66 percent of the data base (table B-10). Those six codes all involved a procedure-following action-selection decision (first digit a 3). Response modality was motor (eye-hand) in four cases and purely verbal in the other two (second digit a 3 or 2). Response complexity level ranged from simple, discrete (third digit a 1) to complex, skilled

and continuous (third digit a 4). The emphasis, however, was found to be on the less complex end of that continuum.

Response codes 3-32 and 3-33 were the only two found to exist for all acoustic systems in the sample (table B-11). However, occurrences of codes 3-31, 3-34 and 3-45 were also fairly evenly distributed across the sample. These latter codes were found to exist for all surface systems and most of the subsurface systems.

Again in this analysis, both the surface and subsurface combination type systems had highly similar codes associated with their operation. The BQR-21 system, however, appears to require skills more similar to those of Combination category systems. In fact, the BQR-21 appears to require skills which are more similar to the combination type systems than to other subsurface passive systems in the group to which it belongs.

When distributed in the Operator Function x Mission Phase matrix response skill factor codes again grouped with the highest frequency under the Search and Track mission phases and the Adjust System Parameter operator function category (table B-12). Considering that four of the six highest frequency response codes were associated with motor activity of various low to moderate complexities suggests that training for ASO should provide experience with a limited set of response alternatives.

Task Difficulty Factor. Taxonomic elements composing this factor are stimulus uncertainty, cognitive information processing and response complexity. It was postulated that, in combination, the elements of this factor portray a general index of task difficulty.

Results of analyses on this factor were much more variable than for any of the other partial code analyses. In the case of the commonality analysis, for example, 25 codes met the one percent criterion (table B-13). For these codes stimulus uncertainty covered the full range of taxonomic possibilities (1 to 6). Likewise response complexity elements ranged from low to high (1 to 5). It appears, however, that overall the stimulus difficulty digit tends to indicate more complexity than the response digit. Thus, being

able to perceive a given stimulus may be more difficult for an ASO than being able to carry out the required response.

One major consistency was found in the character of common task-difficulty factor codes. That finding was that a vast majority of the cognitive elements in those codes was that of data analysis (middle digit a 2). The consistency of this finding does indicate its importance, for it is within the data analysis cognitive factor that are found the activities of filtering, analyzing, cross comparing and correlating stimulus data. These are the types of activities associated with identification and selection of appropriate procedures to follow in making a response. Thus, again in this analysis, procedure following has been found to be central to common ASO tasks.

The distribution of Difficulty Factor codes across acoustic systems was somewhat similar to that found in previous analyses (table B-14). Only two Difficulty Factor codes were found to exist for all systems. Those codes were 3.2.2 and 2.2.2, depicting little stimulus or response difficulty coupled with the data analysis cognitive activity outlined above.

Finally, when difficulty factor codes were placed in the Mission Phase x Operator Function matrix, common codes were again grouped under the Search and Track mission segments and the Adjust System Parameters operator function (table B-15).

Summary of Partial Code Analyses

The skill and knowledge commonality was derived from analyses of the partial task codes. The factors labeled as the Knowledge components of the task involve both perceptual or sensory, and central or cognitive aspects. The perceptual knowledge factors stress the perceptual requirements imposed upon the ASO by the complexities of his environment. The cognitive knowledge factor involves processing of environmental inputs and determining the most appropriate action. Both of these factors emphasize knowing what to do, be it what to look or listen for, or what action is appropriate.

In common tasks, the ASO's data input was found to be primarily visual. Even in those cases where there was an aural input, it was usually in combination with a visual stimulus. The instances of purely aural stimuli were rare and typically associated with acoustic systems in the sample which are the oldest and most nearly obsolete.

Although a predominance of seemingly complex visual displays was found among the newest and most advanced systems, the Perceptual Knowledge Factors accounting for the largest portion of the data base reflected very little stimulus uncertainty. Thus, a majority of the similarity in ASO's jobs across acoustic systems involves extracting data from specific sources involving little ambiguity, i.e., digital readouts or back projection switches.

It is not that using complex displays is not crucial to the ASO's job performance. What the high commonality in perceptual Knowledge Factors indicate is the progressively heavy weighting upon tasks involved in system set-up and configuration. In newer systems the trend appears to be toward vast increases in the number of potential system configurations. Although each step in the Set-up process is relatively simple in itself, the number of these steps can be enormous in some acoustic systems, making the overall task extremely complex and very time consuming. In the current study, heavy use was made of frequency of task occurrence in determining commonality. This resulted in high commonality on the Perceptual Knowledge Factor.

Had only the Perceptual Knowledge factor been considered, two important elements would have been overlooked. When the Cognitive Knowledge factor was analyzed it was found, in addition to recognition, a frequent requirement for detection and discrimination cognitions. This finding has importance because it broadens the commonality base to include more of the ASO's job performance.

Commonalities found in the Sensory Knowledge factor suggest the requirement for an ASO to know how to select and adjust system parameters is very common, but relatively little commonality is found in Operation Knowledge factors. This result suggests that while there may be little commonality in the complexity of the stimulus input with which ASO's must deal, there is very high commonality in those knowledge factors relating to what the operator must do with the stimulus information.

The ASO's job was found to be greatly involved with determining the appropriate procedure or rule to follow. While specific procedures vary as a function of environment, system, or mission, the requirements for procedure following was found to be highly common across all systems, environments, and missions.

The ASO skills identified as highly common across sensor systems involved varying complexities of eye-hand coordination. The range was from pressing a pushbutton (characteristic of the new acoustic systems) to manipulating a cursor and tracking one or more targets. Verbal responses found to be common across systems were most frequently standard reports such as "sonar contact" or the acknowledgment of an order. The implication of this finding is that while the skill requirements associated with the ASO's job are highly common, the importance of those skill requirements is second to that of the knowledge factors discussed above.

To summarize the skill and knowledge commonality observed, the ASO's job requirements, currently and presumable in the future, emphasize a capability to set-up and configure the acoustic system to maximize its information presentation. Ambiguities in this picture are due to the current status of various systems and variabilities in the number of appropriate steps required to optimize the performance of any given system. This depicts a major addition to the emphasis in the ASO's job from simply perceptual processing to include a cognitive problem-solving requirement. As an aside, it was observed that the system optimization function is becoming less of an individual ASO task and more of a team task under sonar supervisor direction.

Although the current study findings do not suggest any major alteration in the curricula for ASO training, the question which must be addressed is whether it is feasible to consider the implementation of a generalized training system to provide those skills and knowledges which are required. This question is addressed in the next section.

Discussion Summary

This study has addressed the question of GASOT feasibility from the standpoint of commonalities in ASO task, skill, and knowledge requirements. Current findings indicate that there are substantial and consistent similarities in the things which operators of various acoustic systems must know

and do. Thus, from the standpoint of common ASO job elements and training requirements, the concept of GASOT does appear feasible.

Implications for Feasibility

The implications of the current data for the feasibility of GASOT are several. First, from the standpoint of the training objectives for a GASOT system, the emphasis of training should be on the proper set-up and use of the equipment.

Perhaps of equal importance is what a GASOT system should not be used to train. The present data indicate quite clearly that the functions of visual and aural display monitoring together with detection, discrimination, interpretation and classification of target signals should not be included in a GASOT system. Although an ASO training program which did not contain the above elements would represent a deviation from the emphasis such functions have historically been given, the current data suggest that those functions can best be trained elsewhere.

A second dimension of feasibility for which the data of this study have importance is that of engineering. Although it is not reasonable, based on the current data, to define whether training hardware needed to support GASOT should be designed as a specific and real acoustic system, or as a general representative system; the common task requirements found here suggest a device for GASO training is clearly within the state-of-the-art from an engineering or simulation standpoint. Visual stimuli found to be common in this study indicate the need for a training simulation which provides the indicators and controls found on existing acoustic system operator consoles. Clearly, since specific simulators already exist for many of the acoustic systems in this study, implementation of this requirement is feasible. Selection of the controls and displays to be included in a simulator intended for generalized training must be based on the specific equipments represented and operator functions being trained.

Trends in Acoustic System Design

A major issue associated with determining the feasibility of GASO training relates to trends in new generation acoustic sensor systems. For the GASOT concept to be of any real value, it is necessary for it to accommodate anticipated changes in the nature of acoustic systems and in the ASO's job.

Although no formal analysis was made of changes in acoustic system design and use during this study, an informal review of systems studied here does indicate what appear to be strong and relevant trends. The current sample of acoustic systems can be divided into two categories. First, the new generation systems. This category includes the SQS-26 Series, SQQ-23 PAIR, BQR-21 and BQQ-5. A second category contains the remaining systems in the current sample and represents the older generation group.

A comparison of the ASO's job in operating systems in these two categories indicates what appears to be a changing role for the operator. For the older systems, this role has involved the major functions of: 1) working with minimally processed acoustic data; 2) determining how and when to optimize system performance; and 3) making target detection and classification decisions based on quite simple displays. The operators of such systems seem to be characterizable as a semi-autonomous with a heavy emphasis on signal detection and processing skills and functions.

By contrast, there appears to be a major change in this role when one examines the ASO's job with new generation systems. First, such operators must deal with highly processed acoustic data. The major impact of this fact is that new and highly sophisticated formats are being used to display such data. Second, new generation systems are typically more capable, providing substantial increases in the number of operational modes. If nothing else, these two factors significantly increase the sheer memory requirement placed upon the operator in recalling which system mode to use under what conditions. Furthermore, there is a definite shift away from the use of unique controls for each specific system function, and toward the use of a general purpose key set in accomplishing system control.

Associated with an increase in the number of possible mode selections is another trend which further influences the operators role. For many of the newer acoustic systems the responsibility for determining which system configuration to select has been completely shifted to the sonar supervisor. In light of the complexities of new systems the need for this shift is completely understandable. It nevertheless has significantly changed the ASO's job.

Additionally, the task of making a detection and/or classification decision has also been further shifted toward supervisory personnel. This shift appears to be due in part to the increased emphasis on integrated acoustic

sensor and weapon systems. In these cases, the major trend is toward integrating the information of several related sensors in ultimately reaching a detection or classification decision. Since any given operator, at most, has information available from a single sensor system, decisions based on the integration of several information sources is reasonably elevated to a supervisory or command level.

The picture which emerges from observations relating to new generation acoustic sensor systems then is one of significant change in the ASO's role. Use of these newer acoustic systems appears to be emphasizing the operator as an information manager rather than as the information gatherer and processor he has historically been.

These trends in equipment design and use, coupled with moves toward the standardization of operator console configuration, seem to indicate that, as time goes on, the ASO's skill and knowledge requirements are going to become more complex and at the same time more general. The generalities which will probably continue to be involved are those of procedure selection, a requirement for the knowledge of how to accomplish system configuration, and the knowledge for determining that the system is, in fact, configured in the way desired.

Thus, it would appear that development of a GASOT concept designed to accommodate anticipated changes in the ASO's role must provide the capability for training:

- A multitude of procedures required for system configuration and control.
- The determination of system configuration status.
- An awareness of supervisor/decision maker information requirement needs.

Functional Specification for a Generalized Acoustic Sensor Operator Training System

Based upon an assumption that the task, skill, and knowledge commonalities found in this study, when coupled with favorable answers to questions remaining to be answered, are adequate to consider development of a generalized ASO training system, this section addresses the nature of such a system.

The major questions to be addressed in suggesting a functional specification for GASOT are:

- What should be trained?
- Who should be trained?
- Where should training be given?
- How should training be accomplished?

An answer to the first question is apparent from the current data. The relatively high level of commonality found in tasks involving simple visual stimuli, procedure following type cognitions and simple eye-hand coordinative responses indicate the focus of generalized training should be on procedural tasks. The additional finding of a high frequency of occurrence of common tasks in the Set-Up, Search, and Track missions further suggests the nature of the procedural tasks to be trained.

A majority of the procedures used in the Set-Up, Search, and Track missions involve knowledge of equipment function and manipulation. This is substantiated by the clustering of common tasks in the Select and Adjust System Parameters, Read Display, and Follow Procedures functions of the Data Categorization Matrix used for this study.

Thus, it would appear that the WHAT question is answered by "the basic system operation procedures." Included here are the specific topics of system functions, control functions, and control-display relationships.

An answer to the question of WHO should be trained seems to flow very nicely from the above. As a generalized approach to training stresses the non-specifics of various sytems, it is assumed that the greatest benefit from such training can be achieved prior to exposure to the operational requirements of any specific sensor system. Within the normal progression of training provided ASO's, the most appropriate application of a generalized course would then be during the initial phases of such training. In fact, the end of basic training or beginning of "A" school appears to be the ideal application. If so, then the type of trainees who would be exposed to the generalized curricula becomes clear. This would be the group who is receiving its initial exposure to acoustic systems.

Perhaps the most obvious answer to the question of "WHERE should training be provided?" is during the initial phases of "A" school. Since there

already exists a common core classroom section of "A" school which is given to all trainees, both subsurface and surface oriented, the addition of a generalized operator section seems to fit logically at that point.

Complete definition of HOW generalized training should be accomplished requires further definition. Needed here is information which clarifies an answer to the further question of whether classroom instruction is adequate or if a simulator is needed. If a simulator is needed, then the degree of commonalities which exist across sensor system functions, displays, and controls must be determined. At issue here is the media required to train various general tasks, skills, and knowledges. Final selection of media must be based on a consideration of whether it can be assumed that transferable general skills can be trained on a single, specific acoustic system or whether some different media is required to attain the necessary level of transfer. Information is needed to demonstrate whether adequate transfer is available from using a single specific system for training and which exact system can be used. On the other hand, if a specific system does not meet the requirements, then consideration must be given to the development of some new media.

An organizational scheme was developed to clarify the options available in determining how and what to train. This scheme organizes available options into a 2 x 2 matrix (table 6).

TABLE 6. CONCEPTUALIZATION OF APPROACHES TO TRAINING

		Hardware: General	Hardware: Specific
Tasks and Skills Trained	General	High Equipment Similarity High Task Similarity	High Task Similarity Low Equipment Similarity
	Specific	High Equipment Similarity Low Task Similarity	Low Equipment Similarity Low Task Similarity

To consider adopting the General Hardware-General Task approach, it is necessary to have a high level of similarity both among the equipments being trained and among the tasks, skills, and knowledge required, or to assume a large degree of skill transfer and accept a low skill commonality requirement coupled with a high level of knowledge commonality. If so, one could then design a single general system simulator and related training course for use with all systems in the sample.

The determination that there is high commonality among systems (controls, displays, functions) but low similarity in the way such systems are used in various environments could lead one to select the approach of training specific tasks but on general hardware. Here, although only a single simulator would be required, a separate training sequence would be needed for each application.

Taking the case in which a high degree of commonality is found across tasks, skills, and knowledge regardless of the sensor system involved, one might select any sensor system as a training vehicle for all required tasks. The assumption is made that there would be a general transfer of training for the skills trained to any subsequent system operated.

Finally, a determination that there is a preponderance of highly unique skills associated with the operation of each individual system for which training is to be provided would lead one to select the Specific Hardware-Specific Skills approach. At the level of specific technology, this obviously is the case. The very issue, however, is whether there are functional similarities which in turn lead to common knowledges which do not require this high fidelity simulation.

The process of specifying the nature of a new training program should follow a specific course: 1) an identification of the functions, controls, and displays existent in the systems for which training is to be provided; 2) an analysis of that data to identify commonalities between systems in those dimensions; and 3) a specification of a representative, general set of functions, controls, and displays to be included in a new training simulator.

Regardless of whether a single specific acoustic system or some "representative" extrapolation of system dimensions is used as the basic media, the situational application of such media suggests how it should be configured. The picture which has developed in answering questions concerning what, who, where, and how to train is one which implies a high volume,

pipeline of relative naive trainees. Thus, it seems that a multi-student station configuration is most appropriate. For such a configuration, it is reasonable to consider from 10 to 20 student stations under the guidance of a single instructor. Advantage should be taken of the benefits available from application of CAI and CMI technology. Thus, the system would be computer controlled rather than "hard-wired." Additionally, decisions are needed concerning the appropriateness of including self-pacing and individualization of instruction features; use of a computer controlled system certainly makes these options available. However, the benefits to be derived from such options must be weighed against their cost.

Use of a computer controlled system also provides several other potential advantages. First are the advantages inherent in the control over the training environment available from using a standardized training program. Secondly, there is a major advantage over conventional acoustic system simulations in the flexibility associated with computer controlled simulations. Finally, substantial reductions in training cost can be expected through employing general training hardware which is capable of being modified through changes to computer software (rather than using operational hardware).

To summarize, the preliminary dimensions of a functional specification for a generalized acoustic sensor operator training which can be identified at this time are:

- What should be trained?
  - Operational procedures for:

    System Set-Up
Search
Manual and Automatic Tracking
  - Generic System Functions
  - Control Functions
  - Display Interpretation (variable stimulus uncertainty)
  - Control-Display Relationships
  - General Function Nomenclature
  - Control-Function Relationships
  - Function-Function Relationships

- Who should be trained?
  - ASOperator Strikers
  - ASO "A" School Input
  - Surface and Subsurface Oriented
  - Watchstanders
- Where should training be given?
  - Shorebased
  - End of Basic Training, or
  - During "A" School, or
  - Special Course
- How should training be accomplished?
  - Classroom Plus Simulator
  - Simulator Characteristics

    Multi-station (10-20)
    Single instructor
    Computer controlled
    CAI
    CMI
    Self-paced
    Individualized
  - Student console characteristics
  - Actual or representative

    controls
    displays
    functions

Feasibility of GASOT Implementation

From the standpoint of deciding whether to initiate a new training approach in the Navy, feasibility appears to be a multidimensional construct. Granting the criterion of sufficient task, skill and knowledge commonality is pivotal to concept validity; it seems that several additional dimensions and questions must also be addressed.

Consideration of those other dimensions and questions led to development of a definition of feasibility which goes beyond the scope of this study. Table 7 presents a summary of the minimum set of dimensions and associated questions thought to be required in providing a complete answer to the question of feasibility.

Since not all of these dimensions were specifically studied in the current investigation, the present results do not provide a complete answer to the question of feasibility. However, these results coupled with the questions remaining to be answered do provide a direction in attaining that answer. The adequacy of task, skill and knowledge commonality has been demonstrated by the current data, and the feasibility dimensions of New Directions and Modification have attained preliminary satisfactory answers. Thus, the major remaining questions relate to the areas of Simulation/ Engineering and Administrative considerations.

From an engineering standpoint, the technology envisioned to be required for a GASOT simulator is well within the state-of-the-art. As pointed out earlier, the major system functions which appear to be required for a GASOT simulator do not involve target display simulations. The exclusion of this requirement is important for it is exactly this area wherein the major difficulty is encountered when simulations are undertaken. For a GASOT simulator the major requirement appears to be that the control-display-system function relationships exist. As high-fidelity simulations of all but one system in the current sample currently exist, the capability for such simulation has already been demonstrated.

A more difficult question to answer relates to the Administrative problems which might be encountered as a function of introducting GASOT No major problems are anticipated from the standpoint of scheduling a GASOT course. If it were offered at the end of Basic Training it would only mean the addition of time for the course. If a decision were made to combine GASOT as part of the "A" school, it could be easily combined with the existing common core portion of that school.

It is at this point, however, where some potential problems arise. It does not appear that a simple addition of a GASOT course segment to "A" school will attain the potential economies available from the use of a generalized approach. Rather, it seems that some further decisions are required concerning what happens after the GASOT segment.

TABLE 7. DIMENSIONS OF FEASIBILITY

Dimension	Representative Questions
Task Commonality	• What amount of commonality exists in the tasks required to operate various sensor systems? • What is the nature of commonality existing between operational requirements for operating various systems? • What metric best describes task commonality? • What amount of task commonality is required to make generalized training feasible?
Skill and Knowledge Commonality	• What amount of commonality exists in the skills and knowledge required to operate various sensor systems? • What is the nature of commonality in the skills and knowledge required to operate various systems? • What metric best describes the commonality of skills and knowledge? • What amount of skill and knowledge commonality is required to make generalized training feasible?
Difficulty of Common Elements	• What metric defines the difficulty of a task? • What metric defines the difficulty of a skill? • What metric defines the difficulty of a knowledge?
Objectives of Training	• What should be the objectives of acoustic sensor operator training? • Is a generalized approach the best, or even a reasonable approach to meeting these objectives?
Administration	• What impact would initiation of generalized acoustic sensor operator training have upon the current ASO training pipeline? • How many ratings would be effected?
New Developments	• What impact would changes in operational sensor systems have upon the design and use of a GASOT were it to be built today?
Modification	• How easily could a GASOT built today be modified to accomodate requirements of new sensor systems?
Simulation/Engineering	• Is the simulation technology available to design a generalized ASO training device? • Are the media available for a GASOT? • What are the functional specifications for a GASOT?

Two alternatives seem reasonable. One, send the GASOT graduate to an at-sea duty station and rely on On the Job Training (OJT) to provide the remaining system-specific training required to become a high proficient operator. Two, compliment GASOT with short, intense system-specific operator training courses at a shore-based facility.

Selection of the first alternative has associated with it the need to be concerned about the ability of the GASOT graduate to advance in rating. Unless the requirements for such advancement are reflected in the GASOT curriculum a "top-out" problem will exist. Associated with the second alternative is the potential continued requirement for a large number of high fidelity system-specific simulators on which to accomplish the system specific training. If such simulators continued to be required, the cost saving potential of using a GASOT approach comes into serious question.

This discussion of implementation feasibility is not intended to imply final answers to the questions at hand. Rather, it is offered to indicate some of the considerations which will have to be addressed in determining the ultimate feasibility of the GASOT approach.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

The following paragraphs summarize current findings and the conclusions which are drawn. A final part of this section contains recommendations for additional research needed to complete the definition of GASOT feasibility.

Summary of Findings

1. There is high commonality in the types of tasks performed by operators of various acoustic sensor systems.

   This conclusion is supported by the fact that only 443 unique task codes were required to represent the original 2483 tasks in the data base. This is an 82 percent reduction in the number of tasks due to commonality.

2. The most representative and frequently performed complete task involved a visual stimulus with low to moderate uncertainty, procedure following type cognitive activity, and a simple motor response.

3. Low commonality was found among tasks involving highly complex activities such as decision making, signal interpretation and classification.

4. High frequency/commonality tasks were found to be associated with all acoustic systems in the current sample.

5. Highly common tasks were consistantly found to be associated with the Set-Up, Search/Detect, and Track mission phases.

6. Occurrence of common tasks was not associated with the Classify or Communicate Mission phases.

7. Highly common tasks were most frequently and consistantly associated with the operator functions of Select and Adjust System Parameters.

Conclusions

1. Generalized Acoustic Sensor Operator Training is feasible based on commonality of tasks performed by ASO's.

2. The nature of common tasks indicates the emphasis of GASOT should be upon equipment operation and procedure following skills.

3. Training of those equipment operation and procedure following skills should focus on equipment Set-up, Search/Detect and Track mission phase requirements.

4. The unique tasks, skills and knowledge required for signal interpretation and classification activities are not appropriate for inclusion in a GASOT program.

5. GASOT should involve an operator console simulation of some type.

6. Although the exact character of that simulation cannot be specified at this time, the current data indicate it need not simulate display contents to a high fidelity.

Recommendations

1. A developmental program should be initiated to complete the definition of GASOT feasibility.

   That program should include at least the following major phases:

   - Establishment of a process for reaching a final decision of GASOT feasibility based on all dimensions included in the construct of feasibility.
   - Development and evaluation of one or more configuration concepts for a GASOT system.
   - Development of complete functional specifications for a single GASOT concept.
   - Development of design specifications

- Production of a prototype GASOT simulator.
- Evaluation of the training effectiveness and transfer obtainable using the prototype simulator.

2. GASOT training program development should focus on, and be used to meet the needs of personnel being given their initial training as operators.

3. Functional and engineering design specifications for a prototype GASOT simulator should permit accomplishment of both training and experimental functions.

   Inclusion of an experimental function is based upon the need to obtain answers pertaining to such important issues as:

   - Control display layout
   - Required fidelity of simulation
   - Cost/effectiveness
   - Transfer of training

Based upon the paucity of task analytic data available for use during this study, a final recommendation is offered.

4. The Navy, perhaps specifically the Naval Training Equipment Center, should institute a process whereby the task analyses, operational sequence diagrams and other similar documents are obtained and retained in a single depository for subsequent reference.

   It is believed that initiation of such a program would prove invaluable for all programs requiring information concerning operator requirements. Since the development of task analytic information is a normal requirement in either the proposal or actual production of all new systems and because it is so difficult to obtain that information after the system has been made operational, the central depository concept appears a reasonable method of insuring data availability for studies of this type.

APPENDIX A

HONEYWELL NUMERICAL TAXONOMY

This taxonomy was developed by Honeywell[10] to provide a standardized method of categorizing behavioral elements of tasks. The taxonomic elements and levels are described below.

ELEMENT-STIMULUS
CATEGORY-MODALITY

Level	Code	Description
Visual	1	Stimulus perceived visually.
Aural	2	Stimulus perceived aurally.
Touch.	3	Stimulus perceived tactually.
Combination	4	Stimulus perceived with more than a single modality--stimulus may have visual, aural, and tactual components.
Other	5	No identifiable external stimulus--stimulus as internal to the man; e.g., passage of time, uncertainty.

ELEMENT-STIMULUS
CATEGORY-INFORMATION UNCERTAINTY

Level	Code	Description
Noise	1	Only noise present, no detected signal.
Simple, one-bit, no uncertainty	2	An "on-off" stimulus providing one bit of information with no uncertainty. Examples: Light is on or off, bell is on or off, "sonar contact" report.

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10 Yaeger, op. cit.

Level	Code	Description
Simple, single-parameter, discrete	3	Stimulus gives two or more bits of information from a small finite number of steps concerning one parameter with little uncertainty. Examples: Digital displays, analog displays, discrete displays and target classification.
Simple, multi-parameter, discrete	4	Stimulus provides two or more bits of information concerning each of two or more discrete parameters with little uncertainty. Example: Target course and speed report.
Complex, multi-parameter, discrete and continuous	5	Stimulus provides two or more bits of information concerning each of two or more discrete or continuous parameters with moderate uncertainty. Examples: moving, dynamic indicators; nonstandard verbal report; single aspect of a CRT display and bearing indicator.
Complex, multi-parameter, continuous	6	Stimulus provides two or more bits of information content about more than two dynamic parameters reflecting continuous steps from a very large finite number with unpredictable and moderate uncertainty. Examples: Multiparameter CRT or hardware displays (A-scan, B-scan); aural sonar signals; discoursive verbal communication between two or more persons.
Complex, multi-parameter	7	Highly complex, multiparameter stimulus which provides more than two bits of information and may contain high uncertainty due to masking, incompleteness, intermittent reception, or not being displayed. A composite of discrete and dynamic information from an infinite number of possibilities with potentially high degrees of information when properly organized. Example: Tactical situation; intelligence brief.

ELEMENT-COGNITION
CATEGORY-PERCEPTUAL PROCESSING

Level	Code	Description
Detection	1	Monitoring, attention, vigilance and detection of the stimulus against background noise. Stimulus presence is sufficient to initiate a response.
Discrimination	2	Requires the simultaneous or sequential comparison of two or more detected stimuli in order to determine that they are the same or different; e.g., differentiation, distinction, differentiation.
Recognition	3	Stimuli require familiarity or past experience for perception.
Identification	4	Requires a naming or labeling activity, but the name of the stimulus is relatively unimportant for task accomplishment. Name need not be specifically stated; e.g., "biological", "submarine", "lightcraft".
Classification	5	Requires a specific name which isolates the stimulus as a member of a specific category of events. Specifying the name is critical to task success. Assignment of the name may involve judgment. Examples: Sonar classification--submarine type, nationality

ELEMENT-COGNITION
CATEGORY-INFORMATION PROCESSING

Level	Code	Description
Reflex	1.	Little processing of stimulus information; leads to an automatic response.

Level	Code	Description
Data analysis	2	Cognitive activities of filtering, reducing, analyzing, cross comparing, and/or correlating stimulus data. Examples: Placing a cursor on the contact marked by a "noisy" background; determining appropriate procedure.
Problem diagnosis	3	Requires identification of a problem through comparison of actual and desired state of affairs, weighting and enumeration of alternate states of affairs.
Concept formation	4	Organization of the information produced as an output of problem diagnosis resulting in the formation of a specific plan, idea or thought solution.
Innovation - creation	5	Involves data analysis (2), concept formation (4) and the production of new information through generalizing from existing data.

ELEMENT-COGNITION
CATEGORY-ACTION SELECTION

Level	Code	Description
In action	1	Selects no overt or perceptible action.
Seeks information	2	Decides to actively seek additional information.
Follow specific rule	3	Decides to follow a specific existing rule or procedure in making a response.
Follow general principle	4	Decides to follow a generalized rule which may be based on existing guidelines for action: may involve using common sense or originality in selecting a response.

ELEMENT-RESPONSE
CATEGORY-MODALITY

Level	Code	Description
Visual orienting	1	Looks at, using only head-eye movement.
Verbal	2	Speaks, reports aurally.
Motor	3	All motor actions, including eye-hand coordination.
Combination	4	The chaining or combination of various response levels.
Other	5	Used for responses which do not fit in other levels.

ELEMENT-RESPONSE
CATEGORY-COMPLEXITY

Level	Code	Description
Simple, discrete	1	Simple on-off type response requiring little or no skill beyond knowing when to respond. Examples: Button push, one-bit verbal response, and switch flip.
Controlled, single-parameter discrete	2	Requires a controlled, discrete act on one parameter. This complexity is used when the response requires little skill beyond differentiating the relevant response from other similar response alternatives. Examples: Select single position of multi-position switch, look up information in a book.

Level	Code	Description
Controlled, multiparameter, discrete	3	Similar to Level 2 but requires a controlled, discrete act on two or more parameters. Examples: Setting a switch and making a verbal report.
Complex, skilled continuous	4	Requires sensory-muscle coordination. Example: Tracking, plotting and aligning.
Compound, multiparameter, continuous	5	Requires a long chain of discrete steps or a single continuous response. Examples: Procedure following, unstructured verbal discourse.
High skill, fine control	6	Requires very high skill levels resulting only from extensive practice.

APPENDIX B

DATA SUMMARIZATION TABLES

Note: On the following tables, B-2, B-6, B-12, and B-15 "No Codes" means that no task of the original data base occurred in this cell. A blank cell indicates a lack of code occurrence for this analysis only.

TABLE B-1. RANKING OF TASK CODES ACCOUNTING FOR GREATER THAN 1% OF THE TOTAL TASK SET

Rank	Task Code	Frequency	% Of Data Base Accounted For	Cumulative % Accounted For
1	42-623-31	273	11.0%	11.0%
2	12-323-31	186	7.5	18.5
3	13-323-32	168	6.8	25.3
4	13-323-31	70	2.8	28.1
5	12-113-22	48	1.9	30.0
6	15-123-21	48	1.9	31.9
7	43-323-32	47	1.9	33.8
8	15-223-34	44	1.8	35.6
9	13-323-21	40	1.6	37.2
10	13-323-11	38	1.5	38.7
11	15-323-34	38	1.5	40.2
12	12-323-32	36	1.4	41.6
13	12-123-11	34	1.4	43.0
(430 codes remaining)				

TABLE B-2. DISTRIBUTION OF COMMON CODES BY MISSION AND FUNCTION

FUNCTION	MISSION				
	Set-Up	Search	Track	Classify	Communicate
Select System Parameters	12-323-31 12-323-32 13-323-31 13-323-32 42-323-31 42-323-32	12-323-31 12-323-32 13-323-31 13-323-32 42-323-31	12-323-31 12-323-32 13-323-31 13-323-32 42-323-31 42-323-32	12-323-1	12-323-31 13-323-31
Adjust System Parameters	13-323-32 15-223-34 42-323-31	12-323-31 12-323-32 13-323-31 13-323-32 15-223-34 42-323-31	12-323-31 12-323-32 13-323-31 13-323-32 42-323-31 43-323-32	12-323-31 13-323-31 43-323-32	No Codes
Monitor Displays Visually		13-323-21 15-123-21	15-123-21		
Monitor Displays Aurally					No Codes
Read Displays Visually	12-123-11 13-323-11	12-123-11 13-323-11 13-323-21	12-123-11 13-323-11 13-323-21 13-323-31 13-323-32 15-123-21	13-323-31	No Codes
Manipulate Controls		15-223-34 15-323-34	12-323-31 15-223-34 15-323-34	15-323-34	No Codes
Follow Procedures	13-323-32		12-323-31 15-323-34 42-323-31		
Detect Signal Presence * All in Syst. 31	12-113-22* 12-123-11 12-323-31 13-323-21	12-123-11		No Codes	
Discriminate Signals Visually			15-223-34		No Codes
Discriminate Signals Aurally	No Codes				No Codes
Interpret Signals					
Classify Signals	No Codes				

TABLE B-3. DISTRIBUTION OF MOST COMMON TASKS BY OCCURRENCES WITHIN SYSTEM

COMMON TASK CODE	SYSTEM													
	SQS-4	SQS-23d-g	SQS-35(v)	SQS-38	SQS-26	SQQ-23pair	BQS-4	BQR-2	BQR-7	BQR-19	BQR-20	BQR-21	BQQ-3	BQQ-5
42-323-31			6	6	5									256
12-323-31	7	2	2	1	6	86	8		1	8	5	29		31
13-323-32	9	16	12	11	25	14	8	3	5	7	9	40	8	1
13-323-31			2	3	8	29								28
12-113-22														48
15-123-21														48
43-323-32	1	5	14	14	10				1		1	1		
15-223-34	4	6	1	1	8						1	15		8
13-323-21					4									36
13-323-11						9								29
15-323-34	2				5	19					1	6		5
12-323-32	6	10			4	1	1	4	5		3		2	
12-123-11						5						29		

TABLE B-4. RANKING OF 12-3XX-XX CODES ACCOUNTING FOR AT LEAST 1% OF THE TOTAL TASK SET

Rank	Task Code	Frequency	% of Data Base Accounted For	Cumulative % Accounted For
1	13-3	441	17.8	17.8
2	42-3	318	12.8	30.6
3	12-3	251	10.1	40.7
4	15-2	147	5.9	46.6
5	12-1	121	4.9	51.5
6	15-3	115	4.6	56.1
7	15-1	111	4.5	60.6
8	43-3	92	3.7	64.3
9	16-1	70	2.8	67.1
10	16-2	46	1.9	69.0
11	16-3	46	1.9	70.9
[illegible]	13-1	42	1.7	72.6
13	26-1	37	1.5	74.1
14	46-2	34	1.4	75.5
15	13-2	33	1.3	76.8
16	16-4	31	1.2	78.0
17	26-2	30	1.2	79.2
18	44-3	30	1.2	80.4
19	41-1	29	1.2	81.6
20	13-4	26	1.0	82.6
21	46-4	26	1.0	83.6
22	45-2	25	1.0	84.6

TABLE B-5. DISTRIBUTION OF MOST FREQUENT 12-3XX-XX CODES BY SYSTEM

	SURFACE						SUBSURFACE							
	Active				Combination		Active	Passive						Combination
Partial Task Code	SQS-4	SQS-23D-G	SQS-35(V)	SQS-38	SQS-26SERIES	SQS-23PAIR	BQS-4	BQR-2	BQR-7	BQR-19	BQR-20	BQR-21	BQQ-3	BQQ-5
13-3	11	23	17	17	42	55	8	5	8	13	13	87	9	133
42-3			17	17	10	1							1	272
12-3	13	13	10	1	10	93	12	4	6	9	8	37	2	33
15-2	5	9	5	5	22	32	8	1	1	5	6	21	3	24
12-1					11	21						37	1	49
15-3	3	3			11	47		2	2	5	5	14		23
15-1	18				19	7		4	4	1		2	1	55
43-3	5	13	18	18	18			1	2		1	16		
16-1	1	3	4	4	22	19				6	2	2		7
16-2	1					5		3	3	3	1	5		25
16-3					2	22		2	2			4		14
13-1							8	2	2	1		28		1
26-1	1	3	2	2	16	3		1	1			4		4
46-2					1			2	2			9		20
13-2					2			2	2	1		20		6
16-4			1	1		5	1			2		10		11
26-2					1	13						3		13
44-3					9									21
41-1					8							21		
13-4										3	9	8		6
46-4		3	1	1	2	8								11
45-2					2		1	8	8	1		1		4
Σ	58	70	75	66	208	331	38	37	43	52	45	329	17	732
% of	66	79	80	71	275	381	44	54	61	64	48	429	29	802
total	88	89	94	93	76	87	86	69	70	81	94	77	59	91

TABLE B-6. DISTRIBUTION OF 12-3XX-XX CODES BY MISSION AND FUNCTION

FUNCTION	MISSION				
	Set-up	Search	Track	Class.	Comm.
Select System Parameters	13-3 42-3 12-3 44-3 13-4	13-3 42-3 12-3	13-3 12-3		
Adjust System Parameters	13-3 42-3	13-3 42-3 12-3 15-2 43-3 16-3 13-2 44-3 41-1 13-4	13-3 42-3 12-3 43-3 46-2 13-2 44-3 15-3	16-3 12-3	No Codes
Monitor Displays Visually		15-1 16-1 41-1	15-1 16-1		
Monitor Displays Aurally		26-1 41-1	26-1		No Codes
Read Displays Visually		13-3 12-1 13-1	13-3 13-4		No Codes
Manipulate Controls		16-3 13-1 15-2 15-3	15-2 15-3 16-3 45-2		No Codes
Follow Procedures		41-1 45-2	46-2 42-3		
Detect Signal Presence	12-1	12-1 16-1 16-4	16-1 41-1	No Codes	
Discriminate Signals Visually	16-2	16-2	15-2 15-3 16-2 13-2		No Codes
Discriminate Signals Aurally	No Codes	26-2	26-2		No Codes
Interpret Signals		46-4	13-2 16-4 46-4		
Classify Signals	No Codes				

TABLE B-7. RANKING OF XX-345-XX CODES ACCOUNTING FOR AT LEAST 1% OF THE TOTAL TASK SET

Rank	Task Code	Frequency	% of Data Base Accounted For	Cumulative % Accounted For
1	323	1318	53.1	53.1
2	123	281	11.3	64.4
3	223	205	8.3	72.7
4	122	80	3.2	75.9
5	113	69	2.8	78.7
6	443	54	2.2	80.9
7	222	50	2.0	82.9
8	233	42	1.7	84.6
9	444	37	1.5	86.1
10	544	37	1.5	87.6
11	322	32	1.3	88.9
12	343	31	1.2	90.1

TABLE B-8. DISTRIBUTION OF MOST-FREQUENT XX-345-XX CODES BY SYSTEM

	SURFACE						SUBSURFACE							
	Active				Combination		Active	Passive						Combination
Partial Task Code	SQS-4	SQS-23D-G	SQS-35(V)	SQS-38	SQS-26SERIES	SQS-23PAIR	BQS-4	BQR-2	BQR-7	BQR-19	BQR-20	BQR-21	BQQ-3	BQQ-5
323	34	60	66	57	124	199	21	12	18	29	27	176	13	482
123	10	3	2	2	57	31	11	7	7	6		76	1	59
223	4	6	1	1	26	26	11	10	10	6	4	29	5	66
122	3	3	4	4	13	2		1	2	4	2	30	1	11
113					6	11		1	1					50
443		3	1	1	4	10		1	1	2	5	17	3	6
222	3	3	2	2	7	12		1	1	5	2	9		3
233					1	8		6	6			12		9
444	2		1	1		6		3	3		3	5	2	11
544	1	1			10	2		1	1			6	2	13
322					4	1				2		5		20
343					1	26					1			3
Σ	66	79	77	68	253	334	43	43	50	54	44	365	27	733
%	100	100	96	96	92	88	98	80	82	84	92	85	93	91

TABLE B-9. DISTRIBUTION OF XX-345-XX CODES BY MISSION AND FUNCTION

FUNCTION	MISSION				
	Set-up	Search	Track	Class.	Comm.
Select System Parameters	323	323	323		
Adjust System Parameters	323	323 223 222 343	323 223 222 233	323 343	No Codes
Monitor Displays Visually		123 122	123		
Monitor Displays Aurally		122			No Codes
Read Displays Visually		323 123	323 322		No Codes
Manipulate Controls		323 322	323 223		No Codes
Follow Procedures		323 233	323		323
Detect Signal Presence	113	123 113 443	123	No Codes	
Discriminate Signals Visually			223 233		No Codes
Discriminate Signals Aurally	No Codes	222 233	233		No Codes
Interpret Signals		443 444	443 233 444	444	
Classify Signals	No Codes		544	544	544

TABLE B-10. RANKING OF XX-XX5-67 CODES ACCOUNTING FOR AT LEAST 1% OF THE TOTAL TASK SET

Task	Task Code	Frequency	% of Data Base Accounted For	Cumulative % Accounted For
1	3-31	637	25.7	25.7
2	3-32	372	15.0	40.7
3	3-34	198	8.0	48.7
4	3-33	187	7.5	56.2
5	3-22	126	5.1	61.3
6	3-21	111	4.5	65.8
7	3-11	98	3.9	69.7
8	3-45	84	3.4	73.1
9	3-15	64	2.6	75.7
10	3-23	49	2.0	77.7
11	3-12	41	1.7	79.4
12	3-35	35	1.4	80.8
13	2-45	34	1.4	82.2
14	4-25	31	1.2	83.4
15	4-32	31	1.2	84.6
16	4-45	31	1.2	85.8
17	2-15	26	1.0	86.8
18	2-32	25	1.0	87.8

TABLE B-11. DISTRIBUTION OF MOST FREQUENT XX-XX5-67 CODES BY SYSTEM

	SURFACE						SUBSURFACE							
	Active				Combination		Active	Passive						Combination
Partial Task Code	SQS-4	SQS-23D-G	SQS-35(V)	SQS-38	SQS-26SERIES	SQS-23PAIR	BQS-4	BQR-2	BQR-7	BQR-19	BQR-20	BQR-21	BQQ-3	BQQ-5
3-31	9	5	10	10	53	142	8	2	5	11	5	31		348
3-32	17	34	35	34	45	45	12	7	11	17	19	75	11	10
3-34	6	9	3	3	21	30		13	13	2	2	46		50
3-33	2	18	6	6	16	63	4	3	4	5	8	26	2	24
3-22	2		2	2	11	3	1			11		24		70
3-21					11	10		1	1			1		87
3-11						20	1					46		31
3-45	18	3	2	2	8	8	5	6	6		2		1	23
3-15					27	3	6					8	3	17
3-23	2	3	1	1	5			4	4		1	25	3	
3-12												40	1	
3-35			8		13	3	7	1	1					2
2-45	2	3			6	1								22
4-25					13	2		2	2	1		3		8
4-32											4	27		
4-45			2	2		2		2	2					21
2-15					10	3		1	1	4	3	1	1	2
2-32						11			1	12	1	10		
Σ	58	75	69	60	239	346	44	42	49	53	45	363	22	715
%	88	95	86	85	87	91	100	78	80	83	94	85	76	89

TABLE B-12. DISTRIBUTION OF XX-XX5-67 CODES BY MISSION AND FUNCTION

FUNCTION	MISSION Set-up	Search	Track	Class.	Comm.
Select System Parameters	3-31 3-32 3-35	3-31 3-32	3-31	3-31 3-32	
Adjust System Parameters	3-33 3-32	3-31 3-32 3-34 3-33 4-32	3-31 3-32 3-33 4-32 3-34		No Codes
Monitor Displays Visually		3-21 3-15 2-45 2-15	3-45 3-15		
Monitor Displays Aurally		2-45			No Codes
Read Displays Visually		3-22 3-21 3-11 2-15	3-21 3-11 3-12		No Codes
Manipulate Controls		3-34 3-35	3-34 3-35		No Codes
Follow Procedures		2-45 3-45	3-35 3-31		3-23
Detect Signal Presence	3-22	3-22 3-15 2-15		No Codes	
Discriminate Signals Visually			3-15 3-14		No Codes
Discriminate Signals Aurally		2-32			No Codes
Interpret Signals			4-25 4-45		3-23
Classify Signals	No Codes				4-25

TABLE B-13. RANKING OF X2-X4X-X7 CODES ACCOUNTING FOR AT LEAST 1% OF THE TOTAL TASK SET

Task	Task Code	Frequency	% of Data Base Accounted For	Cumulative % Accounted For
1	2.2.1	534	21.5	21.5
2	3.2.2	294	11.8	33.3
3	3.2.1	179	7.2	40.5
4	5.2.4	122	4.9	45.4
5	6.2.5	93	3.7	49.1
6	3.2.3	76	3.1	52.2
7	5.2.1	74	3.0	55.2
8	5.2.5	72	2.9	58.1
9	2.2.2	60	2.4	60.5
10	5.2.3	57	2.3	62.8
11	5.2.2	56	2.3	65.1
12	6.2.4	49	2.0	67.1
13	2.1.2	48	1.9	69.0
14	6.4.5	47	1.9	70.9
15	6.2.2	45	1.8	72.7
16	4.2.3	42	1.7	74.4
17	6.3.5	32	1.3	75.7
18	6.4.3	32	1.3	77.0
19	1.2.2	31	1.2	78.2
20	6.4.2	30	1.2	79.4
21	8.2.5	29	1.2	80.6
22	2.2.5	28	1.1	81.7
23	3.2.4	28	1.1	82.8
24	4.2.1	28	1.1	83.9
25	2.2.3	27	1.1	85.0

TABLE B-14. DISTRIBUTION OF MOST FREQUENT X2-X4X-X7 CODES BY SYSTEM

	SURFACE							SUBSURFACE						
	Active				Combination		Active	Passive						Combination
Partial Task Code	SQS-4	SQS-23D-G	SQS-35(V)	SQS-38	SQS-26SERIES	SQS-23PAIR	BQS-4	BQR-2	BQR-7	BQR-19	BQR-20	BQR-21	BQQ-3	BQQ-5
2.2.1	7	5	9	8	27	99	8		1	8	5	61		296
3.2.2	10	21	27	26	36	14	8	3	7	16	10	84	9	23
3.2.1			2	3	18	38						18		100
5.2.4	6	6	4	4	15	22		3	3	1	2	21		35
6.2.5	2	3	4	4	20	8	3	2	2	2	3			40
3.2.3	5	15	6	6	6			4	5		1	27		1
5.2.1	2				7	7				2				56
5.2.5	17	3			23		5	7	7	2			2	6
2.2.2	6	10	8	8	5	2	1	4	5	2	3	2	3	1
5.2.3	1				12	25	2			6	7	1	2	1
5.2.2	3	3				17	2			6	2	17		6
6.2.4	1	3			3	6		4	4	5		3		20
2.1.2														48
6.4.5			1	1	10	12		3	3			3		14
6.2.2			2	2	8	2				3		22		6
4.2.3		1			7	6				1	1	12	1	13
6.3.5					1	4		3	3			3		18
6.4.3	1	4	1	1		13		2	2	1		4		3
1.2.2			2	2								27		
6.4.2	1				2	6				1		10		10
3.2.5	1					2	8				2			16
2.2.5			10	2	5	6	2						1	2
3.2.4					5			2	2	1		18		
4.2.1					9	2		1	1	2				13
2.2.3		1			2	7	2			1		7		7
Σ	63	75	76	67	221	298	41	38	45	60	36	340	18	735
[illegible]	95	95	95	94	80	78	93	70	74	94	75	70	62	92

TABLE B-15. DISTRIBUTION OF X2-X4X-X7 PARTIAL CODES BY MISSION AND FUNCTION

FUNCTION	MISSION				
	Set-up	Search	Track	Class.	Comm.
Select System Parameters	2.2.1 3.2.2 3.2.3 2.2.2 1.2.2 2.2.5 4.2.1 3.2.1	2.2.1	3.2.3 2.2.3 2.2.1	2.2.1	
Adjust System Parameters	3.2.3 5.2.3 1.2.2 2.2.3 3.2.2	2.2.1 3.2.2 3.2.1 3.2.3 2.2.2 5.2.3 6.2.2 4.2.3 6.4.3 1.2.2 2.2.5	2.2.1 3.2.2 3.2.1 3.2.3 2.2.2 5.2.2 6.2.2 3.2.4 4.2.1 2.2.3	2.2.2 6.4.2 2.2.1 3.2.2	No Codes
Monitor Displays Visually		6.2.5 5.2.1	5.2.5 4.2.3 2.2.3		
Monitor Displays Aurally		6.2.5			No Codes
Read Displays Visually		3.2.1 3.2.5 2.2.1	3.2.2 3.2.1 5.2.2 3.2.5		No Codes
Manipulate Controls		5.2.4 6.2.4	5.2.4 6.2.4 3.2.4	5.2.4	No Codes
Follow Procedures			6.3.5 2.2.5 2.2.1		5.2.5
Detect Signal Presence	2.1.2	6.2.4 6.2.2 6.4.2		No Codes	2.2.5
Discriminate Signals Visually			5.2.4		No Codes
Discriminate Signals Aurally	No Codes	5.4.2			No Codes
Interpret Signals		6.4.5 6.4.3	6.4.5 6.3.5 3.2.5		
Classify Signals	No Codes		6.4.2		6.4.5

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